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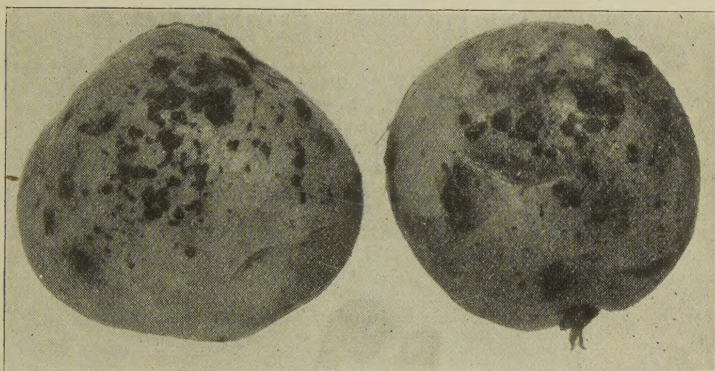
IN CO-OPERATION WITH THE

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GENEVA, N. Y.

The Sterile Fungus Rhizoctonia

AS A CAUSE OF PLANT DISEASES IN AMERICA.



By B. M. DUGGAR and F. C. STEWART.



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THE STERILE FUNGUS RHIZOCTONIA AS A CAUSE OF PLANT DISEASES IN AMERICA

Being a PRELIMINARY REPORT UPON THE OCCURRENCE OF
DISEASES OF PLANTS IN AMERICA CAUSED BY DIFFERENT
FORMS OF THE STERILE FUNGUS RHIZOCTONIA.

By B. M. DUGGAR, Cryptogamic Botanist, Cornell University Agl. Exp.
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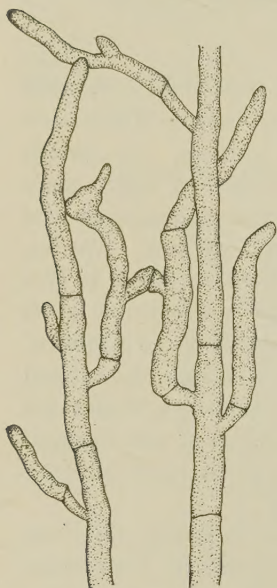
INTRODUCTORY.

Studies on a beet root-rot and a carnation stem-rot in 1898 first drew the writers' attention particularly to the fungus *Rhizoctonia* as a cause of various plant diseases in this country. It needed no extended search to ascertain that this fungus is much more commonly associated with diseases of certain greenhouse and field plants than our economic literature would suggest. During the three seasons that our attention has been directed to this matter, the occurrence of *Rhizoctonia* on some entirely new hosts has been observed, and also upon other hosts new to America. As a preliminary report, it now seems well to bring the subject to the attention of American mycologists. Our work is directed towards a monograph including all known species of this fungus; and it is hoped that these notes will enlist the support of other workers, and some contributions of material.

Besides a brief historical and morphological account, this bulletin concerns itself merely with the presentation of some notes upon the occurrence and destructiveness of American forms observed by the authors. We reserve for the final paper all details of special morphology and physiology of the forms, as well as general matters of taxonomic interest and a discussion of European species. Nothing will at present be said of the limitations or identity of species. The latter is a matter which must be determined largely by cross inoculations, together with morphological studies. Inoculation experiments have been in progress for two years, but they are not yet in shape to be fully reported; hence a presentation of the results will be deferred.

CHARACTERS OF THE FUNGUS.

Rhizoctonia is a form genus established to include certain sterile fungi occurring upon the roots of plants. The members of this genus, however, may be readily located by certain distinguishing characters of the mycelium. In pure culture, moreover, a very characteristic form of growth is to be found. The young hyphæ growing in diseased tissue or in pure culture show a distinctive manner of branching; but as this character is in general the same for all, a description of the beet fungus will suffice for this account. The young



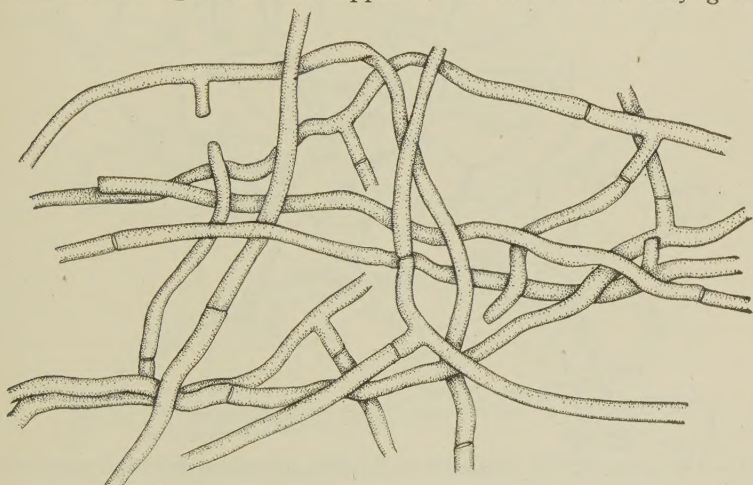
15.—Young hyphæ of the
Rhizoctonia.

branches are inclined to the direction of growth of the parent branch at an angle more or less acute. And the former are somewhat narrowed or constricted where united with the latter, as in Fig. 15. At a distance of a few microns from these places of union, a septum is invariably formed. The young hyphæ are often strongly vacuolate; but later they usually become uniformly granular and more deeply colored. The branching also seems to have occurred more nearly at right angles to the main hypha, and the constriction at the place of union may not be so marked. (See Fig. 16.) On the beet root a short, tufted, or somewhat sporodochia-like growth of the mycelium may also occur. The hyphæ of these tufts are brown, closely septate, constricted at the septa, and often branching

in an irregular or dichotomous fashion, as in Fig. 17. Such hyphæ may eventually break up into hyphal lengths of a single cell or several cells in extent. The individual parts then seem to function as conidia, and germinate within a few hours when placed in suitable conditions. So far as observed, germination is always by the protrusion of a tube through a septum. When several cells are connected, a germ tube from one cell may pass into and through its neighbor, as in Fig. 18, and thus

peculiar appearances may result. Some of the cells of the hyphal chains seem to be devoid of protoplasm, and from neighboring protoplasmic cells the germ tubes seem to pass into such empty cells as readily as directly into the nutrient solution. When the germ tube is from 10μ to 20μ in length, it is invariably narrowed towards the outlet from the parent cell, and a septum forms at a short distance from this outlet, as in Fig. 18. Large, irregular, sclerotial bodies are sometimes found upon the beet, but they are by no means of constant occurrence.

If a part of a diseased beet is placed in a moist chamber, a loose mycelial growth soon appears, and the threads may grow



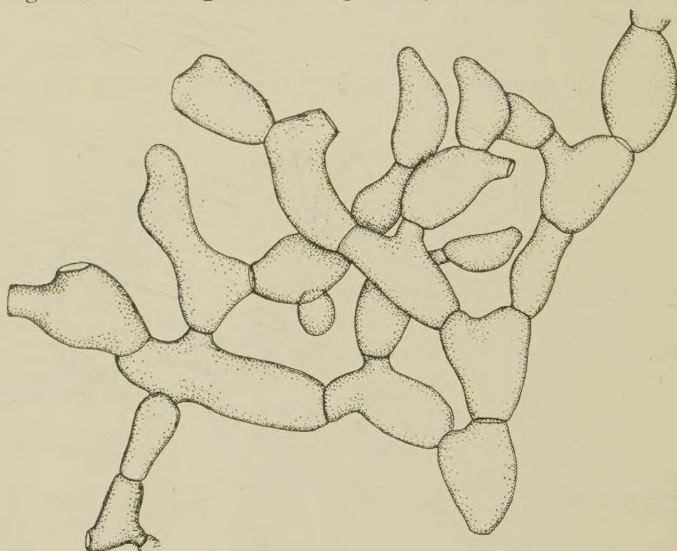
16.—The brown hyphæ which invest the cracks on diseased beets.

out to the extent of half an inch or so. From this it is an easy matter to obtain a pure culture by transferring some of this mycelium to acidulated agar in petri dishes. The fungus grows readily upon acidulated agar, while bacteria are for the most part excluded. The fungus may then be transferred to bean pods, or beet plugs, in test tubes, upon both of which media most forms of *Rhizoctonia* seem to grow well. In pure culture a loose mycelial growth first appears. This becomes brown in time. A short tufted growth may appear later; and usually there is also an effuse or crust-like sclerotial development. In culture the sclerotia are usually irregular in form and brown in color.

At this time it is not desired to enter into a discussion of the slightly different morphological characters which may distinguish the different forms of *Rhizoctonia*.

BRIEF NOTES UPON RHIZOCTONIA IN EUROPE. *Historical.*

The root-destroying fungus *Rhizoctonia* was first discovered by De Candolle¹ in 1815. He named two species: *Rhizoctonia medicaginis*, occurring on *Medicago*, *Trifolium* and related hosts;



17.—The large, closely septate hyphæ which make up the short tufted growth.

and *R. crocorum*, a fungus destructive to crocus bulbs. Of the brief notes published upon other species of the fungus and other host plants until 1851, a comprehensive summary is given by the brothers Tulasne.² They believed that the several species then described were not to be regarded as distinct, and all were thrown together under the name *Rhizoctonia violacea*. In 1858 Kühn³ discussed more at length certain forms of economic importance, and made known some new hosts among agricultural plants.

¹ De Candolle—Mem. d. Mus. d' hist. nat., 1815.

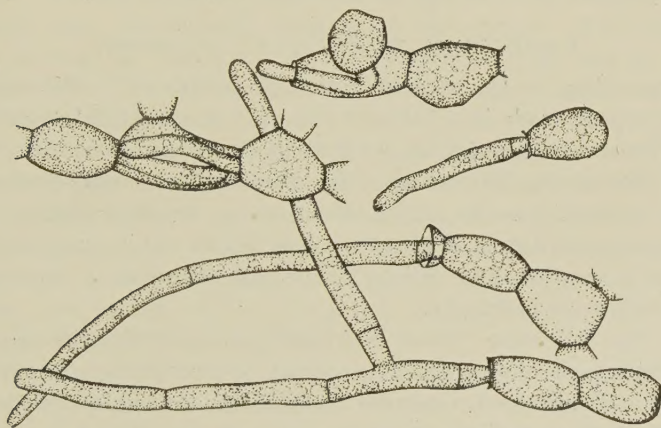
² Tulasne, L. et C.—Fungi Hypogaei, pp. 188-195, 1851.

³ Kühn, J.—Krankheiten der Kulturgewächse, Berlin, 1858.

Fuckel¹ reported a perithecial form, *Leptosphaeria* (*Byssothecium*) *circinans* and also a pycnidial form of *R. medicaginis* D. C. The only claim for the relationship of these forms was based upon their association in nature.

In a similar way other fungi have been subsequently suggested as perfect stages of *Rhizoctonia*, but evidence of genetic relationship is constantly lacking.

Among forms more recently described may be mentioned an oak root-fungus discovered by Hartig.² It was found closely associated with the ascomycetous form *Rossellinia quercina*, so that the reported rhizoctonial stage was described under the latter name.



18. —Germinating cells of the Beet Root-Rot Fungus.

Scholtz³ has described *Rhizoctonia strobil*, causing a disease of the Weymouth pine, and he was unable to establish any connection between the hyphae of this *Rhizoctonia* and those of certain fruiting forms found on plants killed by this disease.

Frank⁴ has recently reported *R. violacea* as destructive to grape

¹ Fuckel.—Botan. Zeitung, **34**, 1861 (p. 250).

² Hartig, R.—Untersuch. aus d. forstbotan. Institut zu München, 1888.

³ Scholtz.—*Rhizoctonia strobil*, ein neuer Parasit der Weymouthskiefer. Verhandl. d. zoolog. - botan. Ges. Wien, **47**: 541-557, 1897.

⁴ Frank, B.—Ein neuer Rebenschädiger in Rheinhessen [Ref. Centrbl. f. Bakt. Parasitenk. u. Infektionskr., **4**, 781, Abth. II.]

vines. A perfect form is reported which he names *Thelephora Rhizoctoniae*.

Rostrup has also described *Rhizoctonia fusca*, the cause of a disease of turnips in Sweden. Comes, Sorauer and Frank have also given full general accounts of the European rhizoctonial diseases in their works on plant diseases.

The list of European host plants now covers a very wide range. The following are the most important plants affected: alfalfa, asparagus, beet, carrot, various clovers, crocus, fennel, geranium, oak, onion, pine, potato and turnip. In all of the above the fungus is primarily a root parasite, and it will be seen that it occurs upon fleshy, herbaceous and woody roots.

RHIZOCTONIA IN AMERICA. *Historical.*

Neglecting for the present any such mentions of *Rhizoctonia* as have been made in "Lists of Fungi," or even brief technical descriptions of new forms, we find in American literature very little concerning *Rhizoctonia*. In 1891 Pammel¹ published some notes on beet diseases, and a beet root-rot was described which he considered due to *Rhizoctonia betæ* Kühn,² this fungus having been mentioned by Kühn, Eidam and others as an important beet disease in Germany.

In 1892 Atkinson³ found in Alabama a sterile fungus causing a damping-off of cotton, also called "sore shin." Later he found and described a similar fungus in connection with the damping-off of various seedlings under glass at Ithaca.⁴

The above are the chief economic references to the occurrence of *Rhizoctonia* in America until the appearance of Bulletin 163⁵ of the Cornell Experiment Station. In December, 1898, the writers presented a paper on *Rhizoctonia* to the Society for Plant Morphology and Physiology at its meeting in New York City.

¹ Pammel, L. H. Bulletin 15. Iowa Agl. Exp. Sta., 1891.

² Kühn, J.—l. c.

³ Atkinson, Geo. F. Some Diseases of Cotton. Bulletin 41, Ala. Agl. Exp. Sta., 1892, pp. 30-39.

⁴ Atkinson, Geo. F. Damping off. Bulletin 94, Cornell Univ. Agl. Exp. Sta., 1895, pp. 339-342.

⁵ Duggar, B. M. Three Important Fungous Diseases of the Sugar Beet. (See pp. 339-352.)

This paper, which was entitled "Different Types of Plant Diseases due to a common *Rhizoctonia*", was published only in abstract.¹ During the past year Stone and Smith² have published an account of lettuce *Rhizoctonia*" and some experiments on its treatment. In the succeeding pages we give our observations upon the occurrence of *Rhizoctonia* upon various plants in America.

ON THE BEAN, *Phaseolus vulgaris*.

Early in August, 1900, we received a few complaints of the ravages of what appears to be an undescribed stem-rot disease of beans. A field of about twenty acres of red kidney beans near Geneva was considerably injured by the disease. The plants were affected as follows: At a distance of from one to two inches above the surface of the soil there was a place on the stem where the tissues were dead and discolored. Frequently, this occurred at the point where the plants commenced to branch. The dead part was dry-rotten clear to the pith, from one-half inch to one inch or more in length, and usually extended entirely around the stem. Being much weakened at the point of attack, it was a common thing for affected plants to be broken over by the wind. When this did not happen, the whole plant slowly dried up and died.

Although larvæ were occasionally found in the diseased stems, it was plain that the trouble was not due to any insect. In all stages of the disease the affected parts were constantly filled with a species of *Fusarium* which at that time, we suspected to be the principal cause of the disease. However, *Rhizoctonia* hyphæ were also present in a great many cases. Sometimes the medulla of dead plants was completely filled with *Rhizoctonia*, and occasionally it was found in early stages of the disease; but it was not constantly present in quantity. The crop preceding the beans was corn.

From Phelps we received bean plants affected with the same disease and some of them showed an abundance of *Rhizoctonia*.

¹ See Bot. Gaz., 27: 129.

² Stone, G. E., and Smith, R. E. The Rotting of Greenhouse Lettuce. Mass. Exp. Sta., Bul. 69.

Mr. F. M. Rolfs¹ also reports having found *Rhizoctonia* on beans on Long Island.

Later, pure cultures from the Geneva material proved capable of producing disease in carnation plants, so that the fungus is very likely pathogenic.

Moreover, on at least two occasions a *Rhizoctonia* has been found producing damping-off among seedling beans in the green house. The disease is characterized by an ulceration of the stem at the surface of the soil and later prostration and death of the seedlings.

ON THE BEET, *Beta vulgaris*.

Our attention was first called to this disease by specimens of affected beets sent to us from Binghamton. A few days afterwards the disease was discovered as a beet trouble of considerable importance at Cattatunk, N. Y. This occurrence has been fully treated in Bulletin 163 of the Cornell Experiment Station, and at this time a summary of these notes will suffice. At Cattatunk a three-acre field was attacked so severely that fully one-third of the crop was lost. Diseased plants are usually found in scattered areas throughout the field; but the fungus undoubtedly passes readily from plant to plant in the row and it has a tendency to spread radially. Cold weather or dry conditions quickly retard the spread of the trouble, and it is much more abundant where the soil is moist or the surface drainage bad.

During hot weather the fungus secures a hold most readily at the bases of the leaves, perhaps because here there is moisture with the slightest rain or dew. Inoculation experiments also demonstrate that in these parts the disease "takes" well. The progress of the injury may be noted by the blackening of the leaf bases, and finally the wilting and prostration of the leaves themselves. The leaves do not, however, turn brown until after they have fallen. When the fungus has worked into the crown and root proper, a browning of those parts is evident, and finally deep cracks may appear, as shown in Fig. 19.

¹ Our thanks are due Mr. Rolfs who has made a great many field observations for us.



16.—*A late stage of Rhizoctonia Beet-Rot, showing the cracking and rotting of the root.*

The brown mycelial threads of the fungus among the diseased leaf bases are evident to the unaided eye, and after the root has become affected, a considerable mycelial web may be found in the cracks and affected parts. A diseased beet sliced lengthwise and placed in a moist chamber yields in a day or two a luxuriant growth of the fungus.

This disease has since been reported to us in the central and the western parts of the State, but specimens were not seen. During the past season it was found again, in the month of August, at Flint and at Phelps, N. Y.; but in neither case was there any serious outbreak of the disease. Specimens collected at the former place showed a considerable development of sclerotia, which bodies had not been previously observed upon the beet. Furthermore, Mr. A. D. Selby has kindly told us that he has found this disease of beets in Ohio during the past autumn.

Inoculation experiments have been made in the field, and these all indicate beyond a doubt that this *Rhizoctonia* may readily produce beet root-rot when the conditions are favorable. Moist conditions are essential for the spread of the disease from plant to plant. Moreover, this fungus taken directly from diseased beets has the power of damping off lettuce and also beet seedlings.

A beet disease due to a species of *Rhizoctonia* has been known to botanists in Europe since 1855; and we are indebted to Professor Karl von Tubeuf, of Berlin, for material of that fungus. It is improbable that the American form is identical with the European. However, the disease found by Pammel¹ in Iowa may be the same as the one which we find in New York.

ON THE CABBAGE AND CAULIFLOWER, *Brassica oleracea*.

Specimens of diseased cabbage seedlings were received from Cairo, Ill., early in 1898. Among growers this disease is improperly called black rot. Sometimes the disease affects very young seedlings, and they are damped off by it, but it is more common after the plantlets have developed one or two true leaves. In the latter, ulcerated areas at or below the surface of the soil often characterize the disease. Plants set in the field are not known

¹ Pammel, L. H. Loc. cit.

to be affected. An examination of the Illinois material showed that a *Rhizoctonia* was constantly present in abundance, and undoubtedly the cause of the trouble. *Rhizoctonia* has also been found causing a disease of cauliflower seedlings at Geneva. The plants were ulcerated at the bases of the stems, sometimes the entire cortex having disappeared.

ON THE CARROT, *Daucus carota*.

The hasty examination of a few carrot fields in August, 1900, resulted in the finding of a few plants affected with *Rhizoctonia*. In a field at Flint, N. Y., two specimens were found, and in another field near Phelps, N. Y., about a dozen more. In every case the plants were affected at the crown. The leaves were all dead, their bases being rotted off and thickly covered with *Rhizoctonia* hyphæ. About half an inch of the upper portion of the root was also rotten, but the disease showed no tendency to run down the root. In some of the specimens there were indications that the rot had been initiated by some larva boring into the crown of the plant.

Kühn¹ and others have reported the occurrence of *Rhizoctonia* on carrots in Germany, but we believe that up to the present time there is no record of the occurrence of such a disease in America.

ON THE CELERY, *Apium graveolens*.

Our knowledge of the occurrence of *Rhizoctonia* on celery is confined to two cases in which it was the cause of a destructive damping off of celery seedlings. Both of these cases were observed in June, 1899. The first one occurred in one of the Station greenhouses at Geneva, and the other in a greenhouse at Poughkeepsie where celery plants were grown extensively. In the latter instance the owner stated that he had had much trouble from damping off. In both of these cases *Rhizoctonia* was undoubtedly the sole cause of the trouble. We are informed that the damping off of celery seedlings is a common occurrence, but thus far we have had opportunity to investigate only the two cases above mentioned.

¹ Kühn, J. Krankheiten der Kulturgewächse, p. 224.

ON THE COTTON, *Gossypium herbaceum*.

The *Rhizoctonia* which is the cause of "sore-shin" or damping off of cotton seedlings has not yet been secured by us; but Professor Atkinson has kindly put at our disposal drawings which he made while studying this fungus in Alabama. He first reported upon it under the caption "sore-shin" in Bulletin 41 of the Ala. Agl. Exp. Sta. In describing it, he says: "The diseased portion of the plant is just beneath the surface of the ground, and is characterized by a shrunken area of a dull reddish-brown color. * * * If the injury remains confined to the superficial tissues, the plant may, and frequently does, recover." The sterile fungus concerned with this disease was isolated, and inoculation experiments demonstrated that the fungus secured was the cause of the damping-off. The description of the fungus in the above mentioned bulletin and the drawings which we have, demonstrate beyond a doubt that the fungus is a form of *Rhizoctonia*.

ON THE LETTUCE, *Lactuca sativa*.

Since 1896 we have repeatedly found lettuce seedlings damping off by a sterile fungus; but it was not until 1898 that it was particularly studied, or its affinities ascertained, and the fungus located as *Rhizoctonia*. Lettuce seedlings affected by this fungus have much the same appearance as seedlings affected by any damping-off fungus. At or near the surface of the ground the tissues become water-soaked in appearance, they are unable longer to support the plantlet, and it falls prostrate on the surface of the ground, the fungus soon invading all parts. This fungus, under favorable conditions may wilt down and destroy, within a day or two, whole boxes of lettuce seedlings. The disease is also readily induced by using pure cultures of the fungus for inoculation purposes.

What is apparently the same fungus has been found several times as a disease of maturer lettuce plants. After the presentation of a preliminary report upon rhizoctonial diseases before the Society for Plant Morphology and Physiology in New York, December, 1898, we received from Mr. R. E. Smith, Amherst, Mass., lettuce plants showing a severe rotting of the leaves.

There was no doubt about the characters of the fungus, and we determined it for Mr. Smith as the *Rhizoctonia* of lettuce. From the characters of the parasitic material, as well as from pure cultures, we considered it identical with the damping-off fungus. The specimens received showed no rotting of the stem, the leaves being the seat of attack. On the older lower leaves the leaf blades alone are affected; but the more delicate inner leaves succumb entirely, blackening and decaying with the progress of the disease. Hyphæ¹ of the fungus occurred scantily over the leaf surface, and a short tufted growth might be found on the inner side of the petioles. These tufts were brownish-white or tawny in color and not so dark as the corresponding growth in culture.

During the past winter this fungus has also been found by Mr. Rolfs on greenhouse lettuce plants at Rochester.

Again, Atkinson² found a form of the sterile fungus studied by him in Alabama, causing damping-off of lettuce seedlings at Ithaca.

Occurring, then, in such widely separated regions it is very probable that it is a fungus very generally distributed.

ON THE POTATO, *Solanum tuberosum*.

Although a *Rhizoctonia*³ disease of potatoes has long been common in Europe, especially in Germany, where it is known under the names "Grind" and "Pockenkrankheit," there is, so far as we are able to ascertain, no record of the occurrence of *Rhizoctonia* on the potato in America. Yet our observations indicate that potatoes in the United States may be quite generally infested by a species of *Rhizoctonia*, as the subsequent discussion will demonstrate.

The occurrence of this fungus upon potatoes was first brought to our attention by Messrs. F. A. Sirrine and F. M. Rolfs, who reported having found it on potato stems collected in the vicinity of Jamaica on Long Island. In the latter part of July the

¹ Compare Stone, G. E., and Smith, R. E. The Rotting of Greenhouse Lettuce, Bulletin 69, Mass. Agl. Exp. Sta. (Hatch), p. 16-17, 1900.

² Atkinson, Geo. F. l. c.

³ *Rhizoctonia solani*, Kühn.

writers visited Long Island and examined several potato fields in the vicinity of Jamaica and Floral Park. A little *Rhizoctonia* was found on the potato stems in all of the fields examined, but it was impossible to determine whether the plants had suffered any injury from its presence. Unfortunately, the potato tops were nearly all dead at that time, the varieties grown in that locality being almost all early varieties. A few tubers were examined but nothing found. On this visit we also had the opportunity of examining some diseased potato stems collected



20.—A potato tuber showing the sclerotia of the *Rhizoctonia*. ($\frac{7}{8}$ natural size.)

on Staten Island by Miss Emma Sirrine, and found them infested with *Rhizoctonia*. A few days later Mr. Rolfs found it at Mattituck, Cutchogue and East Hampton, in the eastern part of Long Island. Here it occurred on late potatoes, and, in one instance at least, there was good evidence that it had killed a considerable number of plants. It was also found at Wading River. There has been much complaint about the premature dying of potatoes on Long Island the past season. What part *Rhizoctonia* played in this trouble is not certainly known, but probably it

was not an important one. Later, the *Rhizoctonia* was found on potato stems in many fields about Geneva, Phelps, Lodi and Oaks Corners.

On August 3 while peeling some scabby potatoes for potato agar we observed that some of the so called "deep scab" ulcers were filled with mycelium composed of rather coarse hyphæ. Microscopic examination showed the hyphæ to be those of *Rhizoctonia*. These tubers had been bought at a grocery in Geneva. Other tubers were then obtained from other groceries and also direct from potato fields in the vicinity of Geneva, and it was found that *Rhizoctonia* hyphæ are of frequent occurrence in scab ulcers.

The next advance made was the discovery of the *Rhizoctonia* sclerotia on the tubers and stems. On September 21 Mr. Rolfs found, in a potato field near Geneva, a tuber bearing a few sclerotia of *Rhizoctonia*. The following day the field was revisited and carefully searched. The crop had been harvested several days earlier, and in the interval rain had washed the dirt from such tubers as had been overlooked and also from the stems of the plants which were left in the field. This facilitated the search and we soon gathered about 30 tubers bearing sclerotia. See Fig. 20. Then we began looking for sclerotia on the stems and had little difficulty in collecting about 25 good specimens. One of these is shown in Fig. 21. Having once seen the sclerotia on the tubers it was easy to find them on almost every lot of tubers examined. We found them, oftentimes in great abundance, on tubers offered for sale at the groceries in Geneva, Poughkeepsie and Ithaca. A wagon load of potatoes offered for sale at Ithaca was so completely overrun with *Rhizoctonia* that it is doubtful if there could have been found in the entire load a single tuber which did not bear one



21.—*Rhizoctonia* sclerotia on a potato stem. (Natural size.)

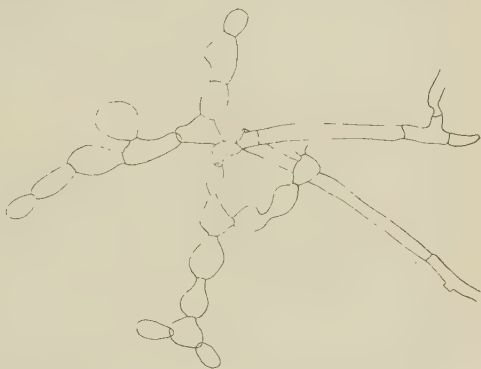
or more sclerotia. Some of the tubers showed several hundred sclerotia each. These tubers were of the variety Rural New Yorker No. 2; and in other respects they were fine, being of large size and almost entirely free from scab and rot. They were grown at Slaterville, near Ithaca. A load of potatoes on the streets of Sayre, Penna., was examined and found to contain a considerable number of tubers bearing sclerotia. We have also seen the sclerotia on tubers grown at Mattituck and Cutchogue. Mr. A. D. Selby has sent us from Wooster, Ohio, potato stems and tubers bearing *Rhizoctonia* sclerotia, showing that the fungus exists in that State. Specimens have also been received from Prof. J. F. Duggar, Auburn, Ala., Mr. F. M. Rolfs, Fort Collins, Colo., and Mrs. F. C. Stewart, who found it at Bassett, Iowa. In short, during the past season many observations on potatoes have been made in different parts of New York State, and *Rhizoctonia* has almost always been found in greater or less abundance. Moreover, it occurs in Alabama, Colorado, Iowa, Ohio, and Pennsylvania, and is probably very generally distributed. Recently the sclerotia have been found abundantly in the markets of Washington, D. C., on New York and Michigan potatoes, and also to a slight extent on one variety of potatoes grown in Maryland.

We have the following proof that the *Rhizoctonia* disease of potatoes existed at Ames, Iowa, as long ago as 1890. In the summer of 1890 Mr. F. A. Sirrine, at that time Assistant Botanist at the Iowa Experiment Station, investigated a potato disease which was doing serious damage on the Station farm. He found the subterranean parts of the affected plants covered with a certain fungus which he at once suspected of being the cause of the trouble. He was unable to identify the fungus. In the course of the investigation an important insect enemy of the potato, the potato-stalk weevil, was discovered¹ in connection with the disease, and as it appeared that this insect was responsible for at least the greater part of the trouble, attention centered upon it and the fungus was allowed to pass into oblivion. Fortunately, Mr. Sirrine made and preserved a camera-lucida pencil drawing of the fungus. This drawing shows that

¹ See Iowa Exp. Sta. Bull. 11: 490.

the fungus studied by Mr. Sirrinc was undoubtedly a *Rhizoctonia*. We have inked in the drawing, without altering it in the least, and publish it herewith. See Fig. 22.

The *Rhizoctonia* attacks only the subterranean parts of the potato plant. The hyphæ occur in the medulla, where they are for the most part very slightly, if at all, colored, and on the outside of the stem and on the roots, where they are often light brown in color. When the hyphæ occur in scab ulcers, those near the surface are brown, while the deeper-lying ones are colorless. The sclerotia on the stems and those on the tubers are essentially the same. They are irregular in outline and vary in size from a mere speck to the size of half a pea or even larger. When dry they are dirt colored, and it is difficult to distinguish them from particles of soil adhering to the tubers. This probably accounts for their having been so generally overlooked. But when wet they become



22.—Hyphæ of the potato *Rhizoctonia* from drawing by Mr. Sirrinc.

dark brown and very conspicuous, particularly on the light skinned varieties of potatoes. In spite of vigorous washing, sufficient to thoroughly remove the soil from the tubers, the sclerotia remain firmly attached. Two housekeepers whose attention we have called to the matter assure us that they have long observed that when potatoes are prepared for baking there are often found dark brown irregular bodies which are exceedingly difficult to remove by washing. It is necessary to use a scrubbing brush to get rid of them. We suspect that these sclerotia are well known to many of the more observant housekeepers.

The amount of damage done by the *Rhizoctonia* when it attacks the subterranean stem and roots of the potato is as yet undetermined, but that the fungus is, in some cases at least, a parasite

there is little doubt. Where it occurs on the tubers, all of our numerous observations go to show that it is not injurious to them. While the *Rhizoctonia* hyphæ may be abundant in scab ulcers there is no evidence that they have anything to do with the formation of the ulcers. The sclerotia are usually seated on the uninjured skin of the tuber. A tuber may bear hundreds of sclerotia and yet be absolutely sound. In this respect our *Rhizoctonia* appears to differ from the European potato *Rhizoctonia*. Some writers report that the latter is a common cause of potato rot. In other respects the two forms are strikingly similar. We are under obligations to Prof. Dr. Paul Sorauer, of Berlin for excellent fresh specimens of the European *Rhizoctonia solani*, from which cultures for inoculation work have been obtained.

ON THE RADISH, *Raphanus sativus*.

In the winter of 1898 diseased radish plants of marketable size were received from Saratoga, N. Y. The disease consisted of a soft rot of the crown, or of large ulcerations in this region. As a rule, the leaves were unaffected until a considerable portion of the root had decayed. It was reported, however, that plants in all stages of growth were affected and killed. It proved to be a trouble of considerable importance with forced radishes, and nearly half of the crop was lost from this disease. It spread rapidly from plant to plant in the row, and from well-established centers of infection. When the material was received, the tissues surrounding diseased areas were infested with hyphæ of a *Rhizoctonia*. These hyphæ were also very abundant superficially, growth being induced, perhaps, by the moist conditions under which the plants had been kept. A culture of the fungus was secured, and with half grown radishes kept under moist conditions the disease was induced; but only a few plants were involved in this experiment. Unfortunately, this culture was afterwards lost, and it has not since been observed as a disease of mature plants. Nevertheless, *Rhizoctonia* has been found occasionally in the greenhouse as a radish damping-off fungus of slight importance.

ON THE RHUBARB, *Rheum rhaponticum*.

For several years a peculiar disease of rhubarb has been observed on Long Island; but until the past season no satisfactory cause of the trouble was evident. During July several rhubarb fields were visited in the vicinity of Jamaica, and in many of these the leaves were dying rapidly, the plants being in an unthrifty condition. There was little or no injury due to the leaf-spot fungus, *Phyllosticta rhei*, and the trouble was evidently of other origin. Affected leaves became dried and shrunk in appearance, and soon fell to the ground. Where a field was badly affected, the majority of hills would show the trouble to the extent of at least a leaf or two. In several instances, apparently from one-fourth to three-fourths of the leaves were already dead. Fields thus affected showed noticeable injury even from a considerable distance.

Close by an affected field, or sometimes even contiguous to it, might be found a field showing the trouble only to a very slight degree. This may have been due to a longer culture of the rhubarb upon one than upon the other area.

An affected leaf breaks off readily just beneath the surface of the ground, and it was found that dead or prostrate leaves had rotted off in this region. The general appearance reminded one strongly of the effect of *Rhizoctonia* upon beets. There was very little superficial mycelium visible to the unaided eye. Microscopic examination showed hyphæ of a *Rhizoctonia* both superficially, and also immediately under the surface where the leaves were rotting. No other fungus was at any time found abundantly associated with the disease, and the *Rhizoctonia* was quite constantly present.

ON ORNAMENTAL ASPARAGUS, *Asparagus sprengeri*.

In May, 1900, a florist on Long Island called our attention to dead patches in a large bench of *Asparagus sprengeri* in one of his greenhouses. The plants were dead and the leaves, which were gray and dry, had a tendency to cling to each other. Closer observation showed that the leaves were bound together with brown threads which proved to be *Rhizoctonia* hyphæ. The disease seemed to be unimportant, being confined to small areas

where the foliage was kept unduly wet by the dripping of water from the glass above. The roots of the affected plants were not examined. Pure cultures of the fungus have been secured.

Knowing that, in Europe, the garden asparagus, *A. officinalis*, is affected by a *Rhizoctonia*¹ root-rot we visited Mattituck, Long Island, for the purpose of searching for the *Rhizoctonia* in the extensive asparagus fields of that locality. Owing to unfavorable weather the search was not as thorough as it should have been, but we failed to find any indications of the presence of *Rhizoctonia* on asparagus roots.

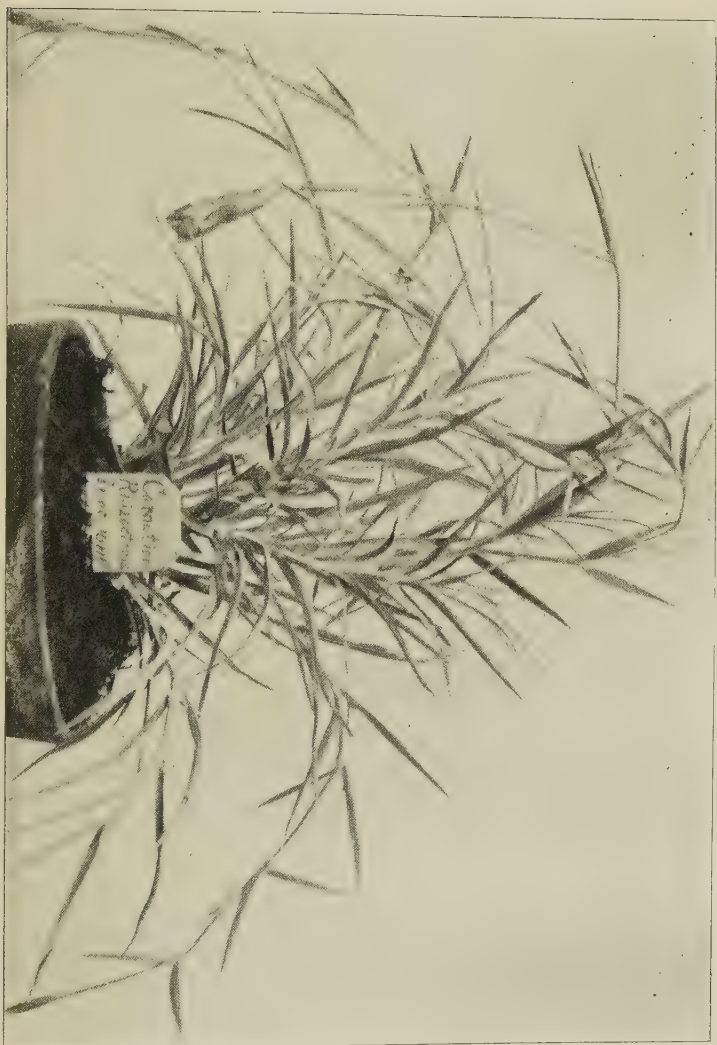
For excellent specimens of the European fungus on the last named host we are also indebted to Prof. Sorauer.

ON THE CHINA ASTER, *Callistephus hortensis*.

In the summer of 1899, Mr. Murrill received from a correspondent specimens of diseased China asters. From his notes we find that the plants presented a wilted appearance, but he observed no fungus either upon branch or leaf. As described by the gardener, the disease might well have been due to a *Rhizoctonia*. An examination of a specimen preserved showed that the lower part of the stem was considerably permeated with hyphæ of a *Rhizoctonia*. The fungous threads were also present superficially, and small crust-like sclerotia had formed upon the stem. There is as yet no further evidence that the fungus found was the cause of the disease. A pure culture of the *Rhizoctonia* was, however, secured, and the fungus will be tested.

During the present season, China asters collected by Mr. Rolfs at Border City, N. Y., also showed a *Rhizoctonia* associated with an aster stem disease. Particular stress cannot be put upon this matter until inoculation experiments are made, for there seems to be at least one other stem disease of asters due to another fungus.

¹ *Rhizoctonia violacea* Tul.



23.—A carnation affected with *Rhizoctonia* Stem-Rot.

ON THE CARNATION, *Dianthus caryophyllus*.

The carnation is subject to a very destructive *Rhizoctonia* disease known to florists by the name of stem-rot. Affected plants wilt suddenly, take on a gray green color, and are soon dead and dry. The seat of the trouble is found to be in the stem at or just below the surface of the soil. The cortex on this portion of the stem is soft rotten and separates readily from the wood. The medulla is rotten and both medulla and cortex are filled with the hyphæ of *Rhizoctonia*. Not infrequently large, brown, irregular sclerotia are found attached to the subterranean portion of the stem and occasionally to the roots.

That *Rhizoctonia* is the cause of this carnation stem-rot has been proven conclusively by inoculation experiments with pure cultures repeated many times. Fig. 23 is from a photograph of a carnation plant killed by artificial inoculation with a pure culture of *Rhizoctonia*. It presents the symptoms typical of the *Rhizoctonia* stem-rot disease.

This stem-rot¹ is one of the most troublesome of the carnation diseases and probably occurs throughout the whole United States wherever the carnation is grown. Frequently entire houses of mature plants are destroyed by it. During the past autumn it appears to have been unusually prevalent. It attacks plants of all ages both in the field and in the greenhouse, and is one of the principal causes of the damping off of carnation cuttings. In greenhouse benches it spreads slowly through the soil from one plant to another; but according to our experiments never through the air, as from one bench to another. Its principal mode of dissemination is by means of affected plants and cuttings.

ON THE SWEET WILLIAM, *Dianthus barbatus*.

Since *Rhizoctonia* is an active parasite on the carnation, it is to be expected that it attacks the closely related *Dianthus barbatus*, and such appears to be actually the case.

¹ There is a somewhat similar and destructive *Fusarium* stem-rot of carnations. See Sturgis, W. C. Twenty-first Ann. Rep. Conn. Agr. Exp. Sta. (1897): 175-181; Prillieux et Delacroix. Compt. Rend. de l' Acad. Science, **129**: 744-745; and Stewart, F. C. Bot. Gaz., **27**: 129-130.

November 5, 1900, we had the privilege of examining a badly diseased plat of about 1600 plants of *Dianthus barbatus* at Queens, Long Island. In the course of the season about 90 per cent of these plants had died from a sort of stem-rot. Several of the dead plants were not completely dry at the time of our visit, so it was possible to get some idea of the nature of the disease and its cause. The symptoms were strikingly like those of the *Rhizoctonia* stem-rot of carnations. The leaves had a sickly, yellowish color and were perfectly limp. The main stem and its numerous branches were soft-rotten at the surface of the soil, so that when an attempt was made to pull an affected plant it broke off readily at that point, leaving the main stem in the ground and many separate branches in the hand. The basal portions of these branches were disintegrated, the wood elements being separated from each other as if the tissues had been macerated.

The rotting stems contained an abundance of *Rhizoctonia*, various other fungi and nematodes, which latter are of course expected to occur in tissue so much decayed. Although not yet tested by inoculation experiments, the indications are that *Rhizoctonia* killed the plants.

It is of interest to note that the plat in which the plants were growing had been planted with carnations in the season of 1899, and they are said to have suffered considerably from *Rhizoctonia* stem-rot.

ON *Coreopsis lanceolata*.

Next to the plat of Sweet Williams above mentioned there were two rows of *Coreopsis lanceolata* which, so the owner informed us, had been considerably diseased during the summer. Only a few of the plants were killed outright, but from many of them the lower leaves had rotted away. The rot seems to start in the base of the petiole where it comes in contact with the soil. The decaying leaves were overrun with *Rhizoctonia*, but what relation the fungus bore to the disease can only be conjectured.

ON THE VIOLET, *Viola odorata*.

In October, 1899, two diseased violet plants were sent to us from Little Falls, N. Y. Both of these plants showed *Rhizoctonia*, leading to the suspicion that violets also are attacked by this fungus; but when a personal examination of the afflicted violet house was made, not another case of *Rhizoctonia* could be found. The trouble was caused by *Glæosporium violæ*. Moreover, the two *Rhizoctonia*-infested plants were potted and placed in one of the Station greenhouses where they thrived and never after showed any ill effects from the presence of the *Rhizoctonia*.

About a year after this experience, interest in the violet *Rhizoctonia* was revived by Mr. Rolfs' discovery of a case of destructive violet stem-rot in a greenhouse at Geneva. Here the affected plants were abundantly infested by *Rhizoctonia*. At about the same time we found it on violets at Floral Park. The plants were in small pots. Some of them had stem-rot, while on others only the bases of the petioles were rotten. The rotten parts frequently contained *Rhizoctonia*.

Thus it appears that *Rhizoctonia* occurs not infrequently on violets, but whether as a parasite or only as a saprophyte can not now be stated.¹

OTHER HOSTS.

In addition to the occurrence of *Rhizoctonia* as an apparent cause of diseases of the host plants already mentioned, there are several other plants upon which we have occasionally found this fungus. For the sake of brevity, we will condense the observations upon these, and bring them together under a single heading, deferring their more extended discussion until further observations and studies have been made upon them.

Rhizoctonia has been found on the roots and trunk of a dead cherry tree from Wright's Corners; as a damping-off disease of white pine and cucumber seedlings; on damped off cuttings of begonia, coleus, verbena, hydrangea, hardy candytuft, and mammoth sage at Floral Park, N. Y.; on mature plants of phlox and

¹ Violet stem-rot is a complex disease not well understood. The fungus *Thielavia basicola* Zopf is generally accepted as being the cause of it. See Thaxter, R. Fifteenth Ann. Rep. Conn. Agr. Exp. Sta. (1891): 166-167.

pyrethrum at Floral park ; and on young plants of snap dragon at Geneva. Mr. Rolfs has observed it on the raspberry, lamb's quarters (*Chenopodium album*), tumble weed (*Amarantus albus*), pigweed (*Amarantus retroflexus*), and on decaying squash stems at Geneva.

PARASITISM OF THE FUNGUS.

In many cases *Rhizoctonia* is truly parasitic, and there can be no question about its being the cause of the diseases with which it is associated. The diseases of beet, carnation, lettuce, and some others with which we have experimented may be readily induced by merely placing in contact with the plant pure cultures of the fungus ; and in time infection will result, provided there is sufficient moisture. Infection results more readily with the carnation by direct insertion of bits of the fungus into the plant. In other cases where the fungus is associated with disease, we have as yet no proof that *Rhizoctonia* is the chief or even partial cause of the trouble. It may sometimes be associated with other fungi, perhaps *Fusarium*. Atkinson¹ has indicated that the sterile damping off fungus of cotton may perhaps have a part to play in the *Fusarium* disease of cotton, at least in initiating the disease.

In spite of the fact that *Rhizoctonia* is at times an effective parasite, the fungus is probably capable of protracted existence upon decaying organic matter in the soil. In this way it may be able to propagate itself, and to spread from plant to plant in the soil even when culture or other means fail to disseminate it. In fact, it seems to be of very general occurrence in the soil, and is likely to be quite commonly found in propagating beds as a cause of damping-off among cuttings and seedlings. From our experience thus far, we venture to predict that few forms of this fungus will be found very selective as to host, and one may well search for it upon the common weeds. The occurrence of this fungus as a disease producing organism is largely dependent upon the conditions, and when by excess of moisture or of heat the plant is placed at a disadvantage, or the fungus favored, the disease is likely to occur.

¹ Atkinson, Geo. F. Some diseases of Cotton. Ala. Agl. Exp. Sta., Bulletin 41, p. 28.

MEANS OF PREVENTION.

Little can be said at present concerning special means of prevention to be adopted for *Rhizoctonia* diseases. Plants growing under the most favorable conditions of moisture, temperature, and nutrition will probably show marked resistance to the attacks of such diseases, so that good sanitary conditions are of the first importance. An excess of moisture and the presence of freshly decaying plant products in the soil will unquestionably favor the disease. Particularly in the propagating and forcing benches is a frequent change of soil advisable. The fungus grows well upon acid media, and liming of the soil is therefore well; but this of itself is not thoroughly effective. If the fungus should become a serious pest in greenhouses, it may sometimes prove practicable to sterilize the soil with steam or with hot water.